Bearing Capacity Analysis of Spun Pile Foundation in Gas Engine for Electrical Power Plant Project of Selayar

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***Abstract*—Gas Engine for Electrical Power Plant Project of Selayar is a power plant which will be built in Selayar Regency. This plant uses gas and biodiesel as a fuel. The facilities needed in the power plant construction includes a Gas Engine, Service Water Tank and Biosolar Tank. This study aims to obtain the allowable bearing capacity of the prestressed spun pile foundation for the three buildings based on soil investigation data of SPT (Standard Penetration Test) at BH-1 (gas engine), BH-2 (service water tank) and BH-3 (biosolar tank). The Meyerhof formula is used for the calculation of ultimate bearing capacity analysis on prestressed spun piles with various diameters for each depth. Calculation of the allowable bearing capacity (Qa) of the foundation at a depth of 19 meters, using a spun pile with a diameter of 300 cm, obtained a Qa value of 94.17 tons at BH-1, 94.20 tons at BH-2, and 74.65 tons at BH-3. Using a spun pile with a diameter of 400 cm, the Qa values were 116.71 tons on BH-1, 117.64 tons on BH-2, and 91.92 tons on BH-3. Using a spun pile with a diameter of 500 cm, the Qa values were 168.67 tons on BH-1, 172.09 tons on BH-2, and 131.49 tons on BH-3. Meanwhile, the values of Qa obtained were 229.85 tons on BH-1, 236.66 tons on BH-2, and 177.79 tons on BH-3 with the use of a spun pile with a diameter of 600 cm.**

Keywords*—*bearing capacity, SPT, spun pile

I. Introduction

Selayar Regency, which is geographically an archipelago, currently uses a Diesel Power Plant to serve electricity needs. A Gas Engine for Electrical Power Plant is planned to be built to increase the electricity supply in Selayar Regency. This power plant requires facilities including gas engine building, service water tank and biodiesel tank. The foundation system is needed to transfer the load of the building into the ground below.

The lower structure as a foundation is generally divided into two types, namely shallow foundation and deep foundation. Selection of this type of foundation depends on the type of superstructure, whether including load construction or heavy load construction and also from the type of soil. For a light load construction and good soil condition, usually using a shallow foundation is sufficient. However, ready for heavy load construction, the deep foundation is usually the primary choice [1].

Commonly used deep foundations include steel piles, concrete piles, mini piles, and bored piles. The choice of deep foundation type is not only adjusted to the load of the working structure, it also takes into account the field conditions, work methods and construction costs.

The function and use of the pile foundation is to move or transfer loads from the construction above it (superstructure) to the hard soil layer, which is very deep. In the implementation of the stake, it is generally fixed perpendicular to the ground, but there is also a battle pile to be able to withstand the horizontal working forces. The angle of inclination that can be reached by the pile depends on the tools used and is also adjusted to the plan [2].

Pile foundation construction parts are made of wood, concrete, and steel, which is used to carry the burdens of the surface to lower surface levels in the soil mass. Concrete slab foundations are usually made in the form of a square cross-section, triangular, and rings (spun pile) [3].

II. Research Methodology

A. *Standard Penetration Test (SPT)*

Standard penetration test (SPT) is a means of obtaining information from the subsurface layers of the

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soil. This method has been standardized as ASTM (American Standard for Testing and Materials) D 1586. SPT testing consists of mounting a soil sampler in the form of a split spoon sampler using a hammer of 140 lbs (63.5 kg) which falls free from a height of 30 inches (76 cm). The number of collision for every 15 cm of SPT tube entry is recorded, namely N1, N2 and N3. Meanwhile, SPT is the value of N, which is N2 + N3.

B. Allowable Bearing Capacity

Bearing capacity is the ability of the soil to bear pressure, or the maximum allowable pressure that works on the ground above the foundation [4].

The ultimate bearing capacity of the prestressed concrete spun pile is calculated based on field data test of SPT using the modified Mayerhof formula for WIKA spun piles with circular cross-sections with a diameter of 350, 400, 500 and 600 mm.

The allowable bearing capacity of the foundation or more precisely the bearing capacity of the soil against the design load which is channelled through the foundation after entering the safety factor (SF)

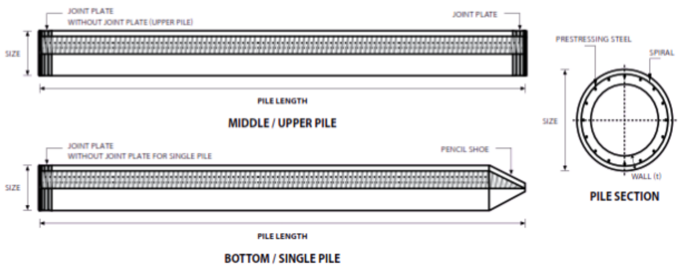

Figure 1. Pile shape

Ultimate bearing capacity, Qu

$$Q_u = 4\, N_b\, A_b + \frac{N\, A_s}{50} - W_p \qquad (1)$$

Allowable bearing capacity, Qa

$$Qa = Qu/SF \qquad (2)$$

In equation (1), Qu is the ultimate bearing capacity (ton), Nb is SPT value at the end of the pile, Ab is pile cross-sectional area (feet^2), N is average of SPT value along with the pile, As is the area of the pile shaft (feet^2), and Wp is unit weight of pile (kg/m, ton/m), shown at Table 1 [5]. While in equation (2), Qa is allowable bearing capacity, and SF is safety factor.

Table 1. Prestressed Concrete Spun Piles Specification

Size (mm)	Thickness Wall (t)	Cross Section (cm²)	Section Inertia (cm⁴)	Unit Weight (kg/m)	Class	Bending Moment Crack * (ton.m)	Bending Moment Break (ton.m)	Allowable Compression (ton)
300	60	452.39	34,607.78	113	A2	2.50	3.75	72.60
					A3	3.00	4.50	70.75
					B	3.50	6.30	67.50
					C	4.00	8.00	65.40
350	65	581.98	62,162.74	145	A1	3.50	5.25	93.10
					A3	4.20	6.30	89.50
					B	5.00	9.00	86.40
					C	6.00	12.00	85.00
400	75	765.76	106,488.95	191	A2	5.50	8.25	121.10
					A3	6.50	9.75	117.60
					B	7.50	13.50	114.40
					C	9.00	18.00	111.50
450	80	929.91	166,570.38	232	A1	7.50	11.25	149.50
					A2	8.50	12.75	145.80
					A3	10.00	15.00	143.80
					B	11.00	19.80	139.10
					C	12.50	25.00	134.90
500	90	1,159.25	255,324.30	290	A1	10.50	15.75	185.30
					A2	12.50	18.75	181.70
					A3	14.00	21.00	178.20
					B	15.00	27.00	174.90
					C	17.00	34.00	169.00
600	100	1,570.80	510,508.81	393	A1	17.00	25.50	252.70
					A2	19.00	28.50	249.00
					A3	22.00	33.00	243.20
					B	25.00	45.00	238.30
					C	29.00	58.00	229.50

C. Location

SPT data is obtained from drilling activities in the location of the Gas Engine Electrical Power Plant Selayar project plan. In Figure 2 below, it can be seen that the drilling location has three points, consisting of BH-1 (Gas Engine), BH-2 (Service Water Tank) and BH-3 (Biosolar Tank).

Figure 2. Drilling hole location

III. Results and Discussion

From the core samples obtained from drilling activity, the soil composition is known. From the composition of soil types in the soil sample, it can be

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determined the classification of soil and rock types which will be very helpful in the validation process of the SPT value obtained.

The soil classification system is a regulation system for different types of soil but has similar characteristics into groups based on their use. The classification system provides an easy language to briefly explain the general properties of soils which vary greatly without detailed explanation [6].

Table 2. Soil and Rock Composition from Geotech Drilling Activities

Hole No	Depth (meter)	Description of Core
BH-1	0.00–2.00	**Silty sand,** black, fine grain sand, very loose
	2.00–18.00	**Fine sand,** dark grey, loose, consist of fine gravel
	18.00–46.30	**Sandy Tuff (volcanic rock),** yellowish-brown, hard, some consist of pumice
	46.30–50.00	**Limestone,** light grey and white, hard, some consist of coral
BH-2	0.00–1.80	**Silty sand,** black, fine grain sand, very loose
	1.80–13.00	**Fine sand,** dark grey, loose, consist of fine gravel
	13.00–22.00	**Fine sand,** light grey, loose to dense, saturated.
	22.00–46.20	**Sandy Tuff (volcanic rock),** yellowish-brown, hard, some consist of pumice
	46.20–50.00	**Limestone,** light grey and white, hard, some consist of coral
BH-3	0.00–3.00	**Silty sand,** dark brown, fine grain sand, very loose.
	3.00–22.00	**Fine sand,** dark grey, loose, consist of fine gravel
	22.00–43.20	**Sandy Tuff (volcanic rock),** yellowish-brown, hard, some consist of pumice and coral
	43.20–50.00	**Limestone,** light grey and white, hard, some consist of coral

SPT value is obtained from each drilling hole. The SPT value is compared with the type of soil sample presented in Table 2. The SPT value describes the level of soil density, a large SPT value should also be obtained from a soil sample that is dense or has good bearing capacity.

SPT testing is carried out at two-meter intervals, or when the cored soil samples show different types of soil and levels of density. SPT testing is stopped if obtained an N-SPT value >60 three times in a row.

Table 3. N-SPT Value from Each Drilling Hole

Depth (m)	N-SPT Value		
	BH-1	BH-2	BH-3
3	16	20	12
5	24	19	23
7	23	12	26
9	23	18	13
11	22	25	13
13	24	34	22
15	27	12	24
17	31	13	42
19	41	45	30
21	60	60	57
23	60	60	60
25	60	60	60

From the N-SPT values presented in Table 3, the foundation bearing capacity then can be calculated. The type of foundation chosen in this study is spun pile with specifications from the production of PT WIKA. Specifications (diameter, unit pile weight, allowable axial load) of spun piles are presented in Table 1.

The bearing capacity of the pile is calculated using the Meyerhof formula (equation (1)). The unit used in this formula is feet, so a unit conversion is needed from the parameters presented in Table 1.

The calculation of the bearing capacity of piles is taken by varying the pile diameter of 300, 400, 500, and 600 cm.

In Figure 3, a graph of the allowable bearing capacity at the BH-1 location is the location for the construction of the foundation for the gas engine. In this graph, it can be seen that the deeper the pile is, the greater the value of the bearing capacity of the pile, the greater the diameter of the pile the greater the bearing capacity of the pile. At a depth of 19 meters, the Qa values (the allowable bearing capacity) of the foundation for a diameter of 300 cm is 94.17 tons, a diameter of 400,

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500, 600 cm, respectively, the Qa values are obtained at 116.71, 168.67, and 229.85 tons.

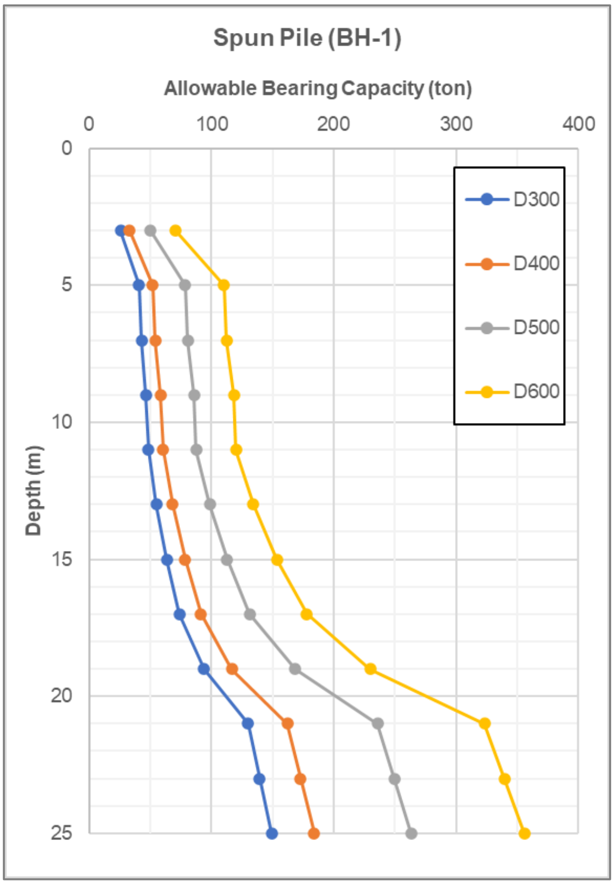

Figure 3. Allowable bearing capacity at BH-1 (Gas Engine Location)

In Figure 4, a graph of the allowable pile bearing capacity at the BH-2 location is the construction site for the foundation for the service water tank. In the graph, it can be seen that the deeper the pile is, the greater the value of the bearing capacity of the pile to a depth of 13 meters, then decreasing to a depth of 17 meters, at a depth of 19 meters there is an increase again. This pattern follows the SPT value pattern. At a depth of 19 meters, the Qa values (the allowable bearing capacity) of the foundation for a diameter of 300 cm is 94.20 tons, a diameter of 400, 500, 600 cm obtained the value of Qa of 117.64, 172.09, and 236.66 tons, respectively.

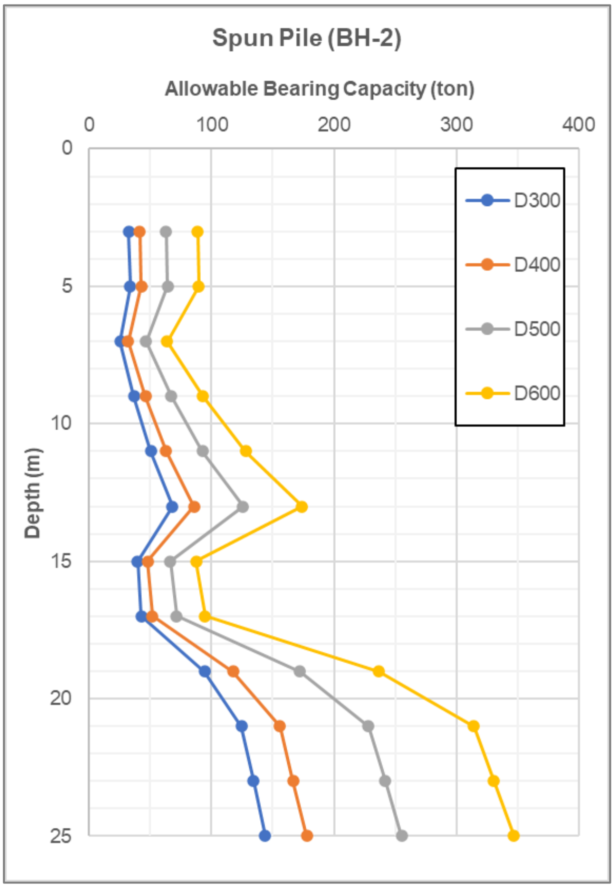

Figure 4. Allowable bearing capacity at BH-2 (Service Water Tank Location)

In Figure 5, a graph of the allowable bearing capacity is presented at the BH-3 location, which is the location for the construction of the foundation for the biodiesel tank. In this graph, it can be seen that the deeper the pile is, the greater the value of the bearing capacity of the pile, the greater the diameter of the pile the greater the bearing capacity of the pile. At a depth of 19 meters, the Qa values (the allowable bearing capacity) of the foundation for a diameter of 300 cm is 74.65 tons, a diameter of 400, 500, 600 cm, respectively, the Qa values are 91.92, 131.49, and 177.79 tons. In Figure 5, it can also be seen that a decrease in the bearing capacity of the pile at a depth of 9 to 15 meters and then an increase again from a depth of 17 meters.

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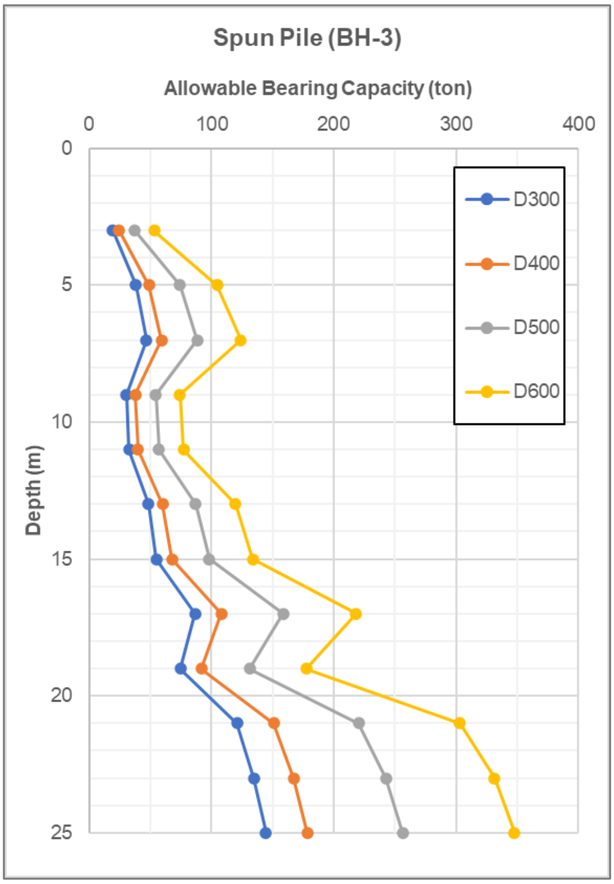

Figure 5. Allowable bearing capacity at BH-3 (Biodiesel Tank Location)

IV. Conclusion

From the above discussion, it can be concluded as follows:

1. Allowable bearing capacity at BH-1 (foundation for the gas engine), at a depth of 19 meters, the Qa values (the allowable bearing capacity) of the foundation for a diameter of 300 cm is 94.17 tons, a diameter of 400, 500, 600 cm, respectively, the Qa values are obtained at 116.71, 168.67, and 229.85 tons
2. Allowable bearing capacity at BH-2 (foundation for the service water tank), at a depth of 19 meters there is an increase again. This pattern follows the SPT value pattern. At a depth of 19 meters, the Qa values (the allowable bearing capacity) of the foundation for a diameter of 300 cm is 94.20 tons, a diameter of 400, 500, 600 cm obtained the value of Qa of 117.64, 172.09, and 236.66 tons, respectively.
3. Allowable bearing capacity at BH-3 (foundation for the biodiesel tank), at a depth of 19 meters, the Qa values (the allowable bearing capacity) of the foundation for a diameter of 300 cm is 74.65 tons, a diameter of 400, 500, 600 cm, respectively, the Qa values are 91.92, 131.49, and 177.79 tons.

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